Army Research Laboratory

# Comparison Between the WSCAFFIP Model and Measured Rotorcraft Sound Pressure Levels

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ARL-SR-111

April 2002

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| **1. REPORT DATE** *(DD-MM-YYYY)*<br>April 2002 | **2. REPORT TYPE**<br>FINAL | **3. DATES COVERED (From - To)** |
| **4. TITLE AND SUBTITLE**<br>Comparison Between the WSCAFFIP Model and Measured Rotorcraft Sound Pressure Levels | | **5a. CONTRACT NUMBER**<br><br>**5b. GRANT NUMBER**<br><br>**5c. PROGRAM ELEMENT NUMBER** |
| **6. AUTHOR(S)**<br>John Williams | | **5d. PROJECT NUMBER**<br><br>**5e. TASK NUMBER**<br><br>**5f. WORK UNIT NUMBER** |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**<br>U.S. Army Research Laboratory<br>Information & Electronic Protection Division<br>Survivability Lethality Analysis Directorate (ATTN: AMSRL-SL-EM)<br>White Sands Missile Range, NM 88002-5513 | | **8. PERFORMING ORGANIZATION REPORT NUMBER**<br>ARL-SR-111 |
| **9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**<br>U.S. Army Research Laboratory<br>2800 Powder Mill Road<br>Adelphi, MD 20783-1145 | | **10. SPONSOR/MONITOR'S ACRONYM(S)**<br><br>**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**<br>ARL-SR-111 |

**12. DISTRIBUTION/AVAILABILITY STATEMENT**

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**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

Field acoustic measurements of a hovering rotorcraft were made and the attenuation of each of its harmonics was computed as a function of slant range. Windows Scanning Fast Field Program (WSCAFFIP), an acoustic propagation model, was run to compute theoretical attenuations for the conditions existing during the measurements. Comparisons were made between the measured and modeled attenuations. Generally, the measured values supported the model, with some discrepancies at higher harmonics and lower altitudes, as well as a few slant ranges.

**15. SUBJECT TERMS**

acoustics, acoustic attenuation, rotorcraft, WSCAFFIP

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
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## Preface

Personnel from the U.S. Army Research Laboratory, Survivability/Lethality Analysis Directorate (SLAD) made acoustic measurements of a rotorcraft hovering at various ranges and altitudes. SLAD computed the narrow-band spectrum at each hover location and found the sound pressure level (SPL) of each peak. The relative attenuation of each peak as a function of range could then be computed. SLAD also ran the Windows Scanning Fast Field Program (WSCAFFIP) model for the conditions at the time of the measurements. This technical note presents comparisons between measured sound attenuation from a hovering rotorcraft and theoretical attenuation from the WSCAFFIP model.

# Contents



**Figures**

# Executive Summary

## Introduction

The U.S. Army Research Laboratory (ARL), Survivability/Lethality Analysis Directorate (SLAD) conducted acoustic measurements of rotorcraft hovering at various distances from microphones. The attenuation of these measured sound pressure levels (SPL) were compared to theoretical attenuations generated by the acoustic propagation modeling Windows Scanning Fast Field Program (WSCAFFIP). The purpose of this report is to present the comparison between measured sound attenuation and theoretical attenuation of a hovering rotorcraft using recorded acoustic and meteorological data.

## Methodology

SLAD set up a microphone at a surveyed point on the ground, and surveyors surveyed and marked several points at various distances. The rotorcraft hovered over the marked points at two different altitudes while the microphone's output was recorded. Meteorological data were also recorded.

SLAD found the SPL of each peak in the rotorcraft's narrow-band spectrum. These SPL's were tabulated according to their slant range and altitude. SLAD ran WSCAFFIP using the recorded meteorological data and applying a 1976 U.S. Standard Atmosphere[1]. The measured attenuations were then compared with those from the WSCAFFIP output. The comparisons are shown in a series of plots.

## Results

The plots given in section 3 of this report show the comparison between the WSCAFFIP theoretical losses and the measured losses. Each plot shows the relative SPL of one harmonic of the rotorcraft at one altitude along with the WSCAFFIP attenuation as the slant range increases.

Generally, the measured attenuation levels follow the WSCAFFIP model, and they are reasonably close for most points in the first six harmonics. There are some notable differences between the measured data and the model, however:

- The measured attenuations of the higher harmonics at the low altitude fall off much more rapidly than the model.
- The second range point for the low altitude data appears to dip unnaturally for the third, fourth, fifth, and sixth harmonics.
- The third range point for the high altitude data appears unnaturally high for some harmonics, in particular the first, third, eighth, ninth, 10th, 11th, 12th, and 13th.

[1]U.S. Standard Atmosphere, 1976, National Geophysical Center, National Oceanic and Atmospheric Administration, 325 Broadway, Boulder, CO 80303; website: nssdc.gsfc.NASA. gov/space/model/ atmos/us_standard.html

These differences may be due to measurement error or some environmental condition that was not accounted for, such as a wind gust. Since there were more discrepancies in the low altitude data, the ground effects may have been greater than modeled by WSCAFFIP. Nevertheless, differences should be expected between measured data and a model—these data support the model reasonably well.

## Conclusions

The measured SPL data from a hovering rotorcraft generally supported the theoretical attenuation levels from the WSCAFFIP model. There were some discrepancies, but these could be due to an incomplete knowledge of meteorological conditions between the sound source and receiver at all hover points. Also, the ground may have attenuated the sound to a greater extent than the model indicated, especially at the higher frequencies.

## Recommendations

In any future investigations of this sort, SLAD recommends that meteorological data be taken at several altitudes and points between the receiver and sound source. This is probably the most important part of the WSCAFFIP model, and the one that will best facilitate the modeling of sound propagation through the atmosphere.

# 1. Introduction

## 1.1 Background

The U.S. Army Research Laboratory (ARL), Survivability/Lethality Analysis Directorate (SLAD), has conducted numerous acoustic measurements of rotorcraft. In one of these measurements, a rotorcraft hovered over known points at various distances from the microphones. This presented an excellent opportunity to measure the attenuation of sound from a stationary source under real-world conditions.

SLAD has also run acoustic data through models that attempt to calculate a rotorcraft's detectability. For one of these models, an acoustic propagation program is run first, and the measured sound's attenuation is calculated from the program's output. The program is called the Windows Scanning Fast Field Program (WSCAFFIP), and it produces a table of sound attenuation values as a function of range and frequency. It is only natural, then, to compare the actual sound attenuation measured from a hovering rotorcraft to the theoretical attenuation calculated by WSCAFFIP.

## 1.2 Purpose

The purpose of this report is to present the comparison between measured sound attenuation and theoretical attenuation of a hovering rotorcraft using recorded acoustic and meteorological data. This comparison will be done at each of the harmonics in the rotorcraft's acoustic spectrum.

# 2. Methodology

## 2.1 Measurements

SLAD personnel setup a microphone near the ground and marked points on the ground at various distances from the microphone. The pilot of the rotorcraft could see these markings from the air. The pilot hovered over each point for about a minute, while the signal from the microphone was recorded, and at two altitudes called "low altitude" and "high altitude." All points were surveyed so that the distance between the rotorcraft and microphone was known for each hover point. Figure 1 shows the basic setup.

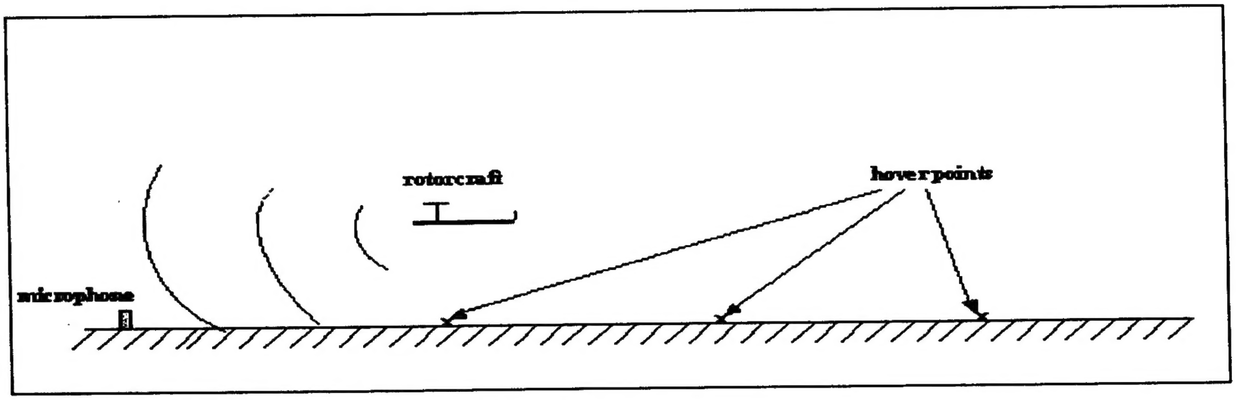

**Figure 1. Setup for hovering measurements.**

A meteorological station was setup nearby, about 2 or 3 m above the ground, and recorded air temperature, humidity, barometric pressure, wind speed, and wind direction. Generally, wind speeds were low for these measurements.

### 2.2 Analysis

SLAD averaged about eight narrow-band spectra from each hover point, and found the sound pressure level (SPL) of each peak from each averaged spectrum. Each peak was a harmonic of the sound produced by the rotorcraft's rotors. These SPL's were tabulated by harmonic, rotorcraft altitude, and hover point. Figure 2 shows a typical spectrum of the rotorcraft, albeit one that is not averaged.

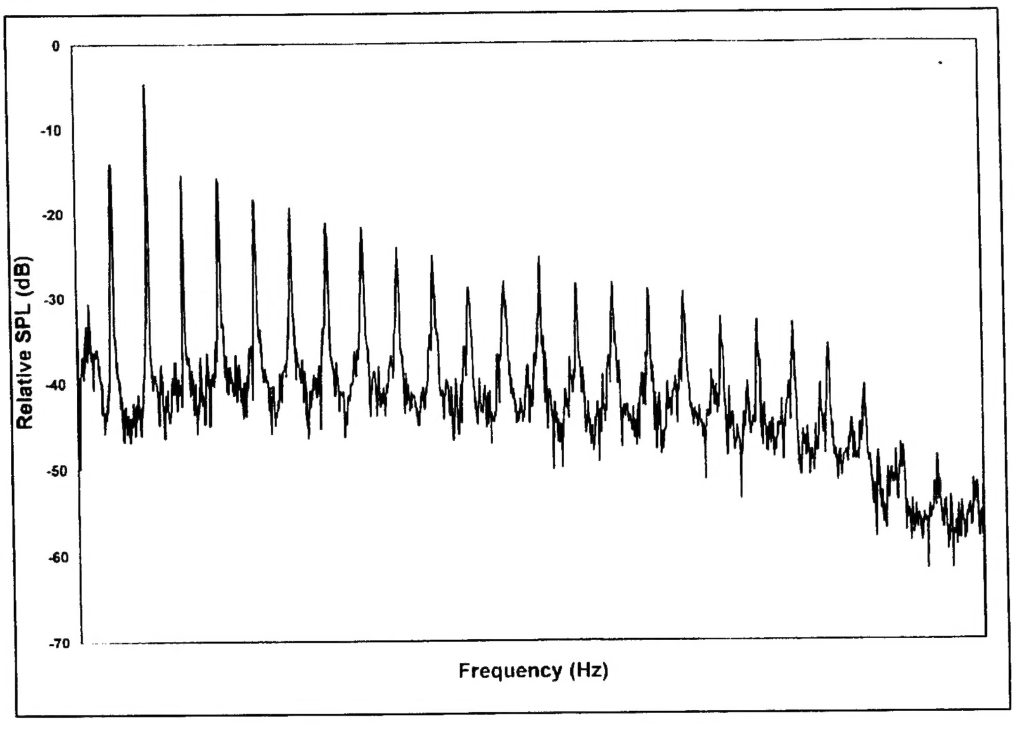

**Figure 2. Rotorcraft spectrum.**

SLAD ran WSCAFFIP for the conditions present at the time of the measurements. WSCAFFIP's basic inputs are a meteorological profile, relative geometry of the source and receiver, and ground characteristics. The meteorological profile includes the temperature, relative humidity, air pressure, wind velocity, and wind direction at different heights above the ground. Since these

were measured at only one height, SLAD used a U.S. Standard Atmosphere[1] to generate a meteorological profile. The survey and hover altitudes gave the relative geometry of source and receiver. The ground was covered with thick grass. SLAD interpolated the WSCAFFIP propagation table by frequency and slant range to obtain each harmonic's theoretical loss at each hover point. These losses were compared to the measured losses.

## 3. Results

Figures 3 through 28 show the comparison between the WSCAFFIP theoretical losses and the measured losses. Each figure shows the relative SPL of one harmonic at one altitude as the slant range increases. The SPL at the hover point closest to the microphone was set to the value from the WSCAFFIP propagation table, and then this value was further adjusted to an arbitrary value. All ranges were normalized, and the normalization value was different between the high and low altitudes. Generally, the measured attenuation levels follow the WSCAFFIP model, and they are reasonably close for most points in the first six harmonics. There are some notable differences between the measured data and the model; however

- The measured attenuations of the higher harmonics at the low altitude fall off much more rapidly than the model.
- The second range point for the low altitude data appears to dip unnaturally for the third, fourth, fifth, and sixth harmonics.
- The third range point for the high altitude data appears unnaturally high for some harmonics, in particular the first, third, eighth, ninth, 10th, 11th, 12th, and 13th.

These differences may be due to measurement error or some environmental condition that was not accounted for, such as a wind gust. Since there were more discrepancies in the low-altitude data, the ground effects may have been greater than modeled by WSCAFFIP. Nevertheless, differences should be expected between measured data and a model—these data support the model reasonably well.

[1]U.S. Standard Atmosphere, 1976, National Geophysical Center, National Oceanic and Atmospheric Administration, 325 Broadway, Boulder, CO 80303; website: nssdc.gsfc.NASA. gov/space/model/ atmos/us_standard.html

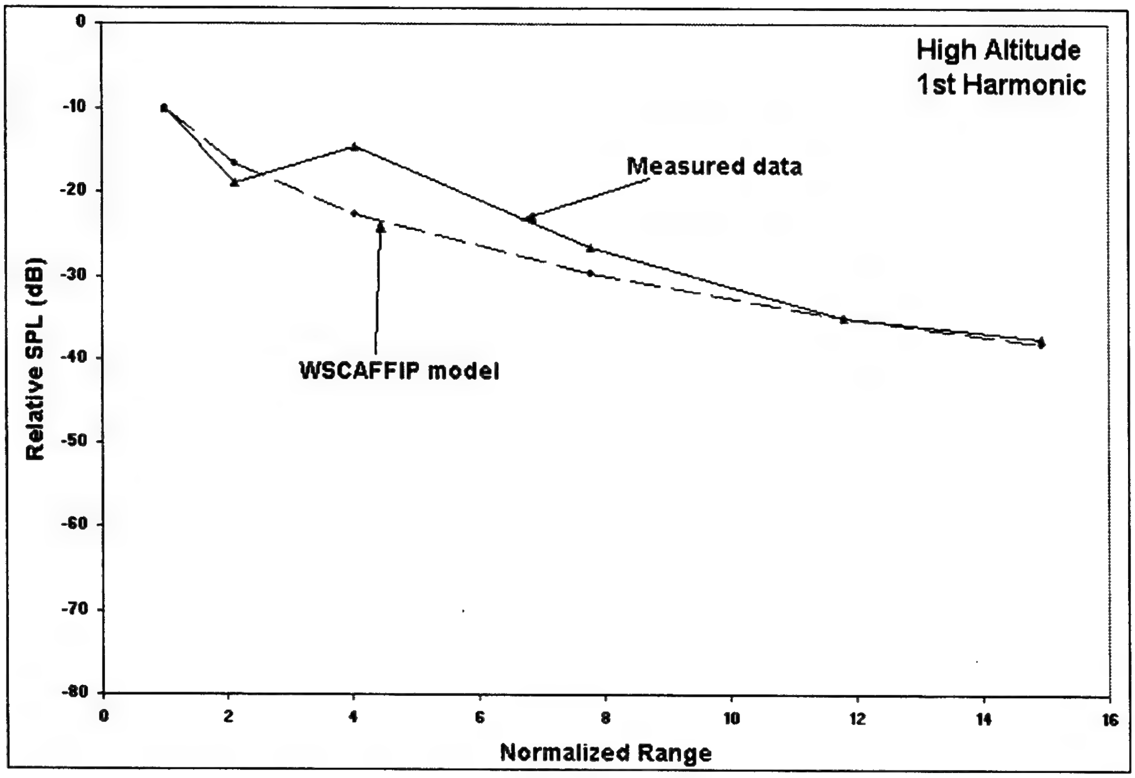


Figure 3. Comparison between WSCAFFIP model and measured data for first harmonic at high altitude.

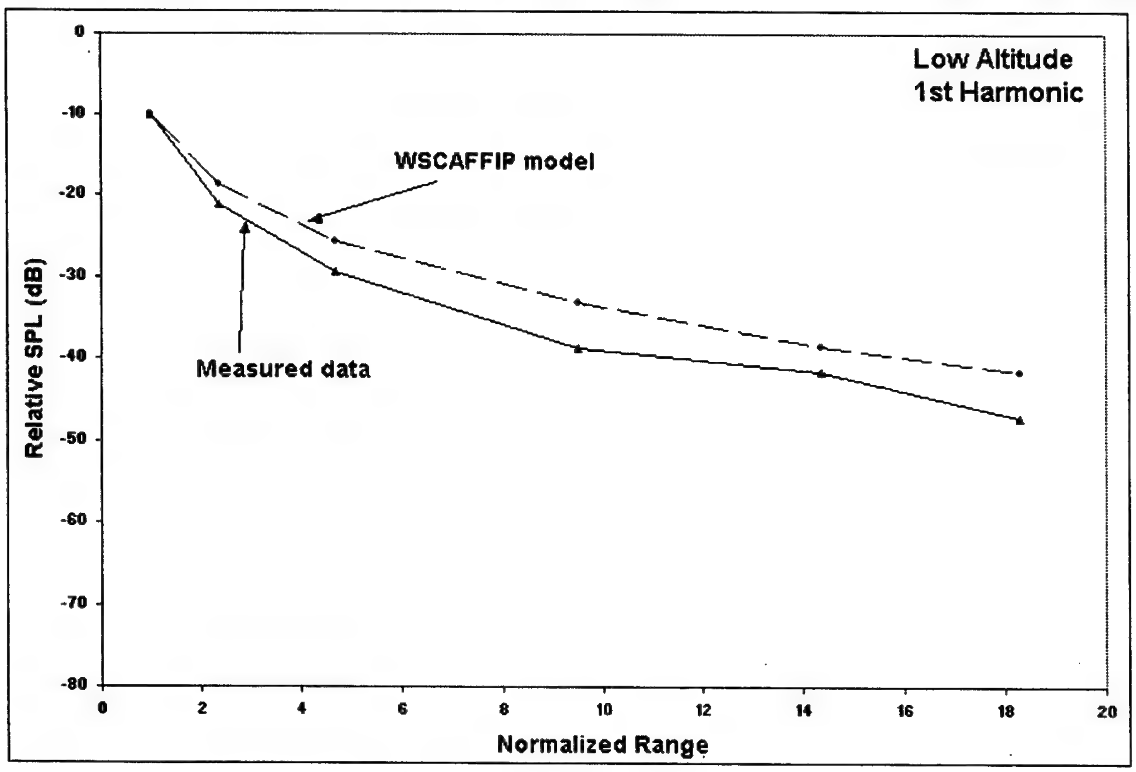


Figure 4. Comparison between WSCAFFIP model and measured data for first harmonic at low altitude.

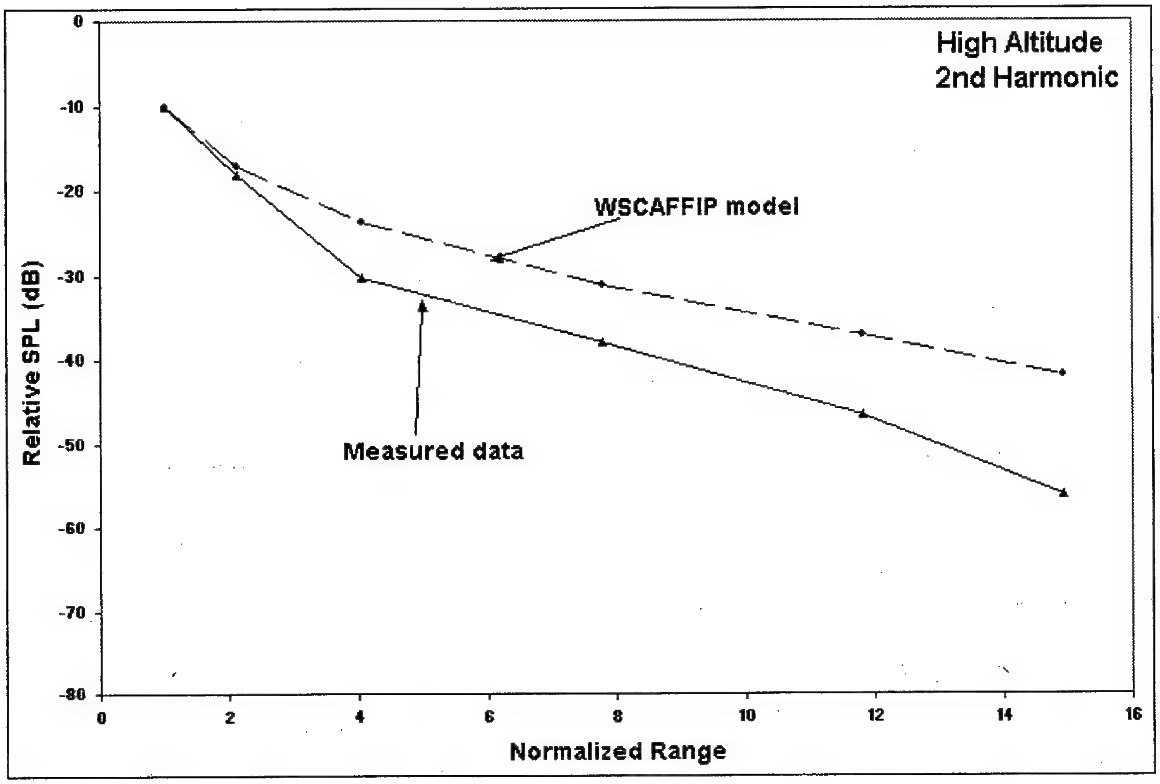


Figure 5. Comparison between WSCAFFIP model and measured data for second harmonic at high altitude.

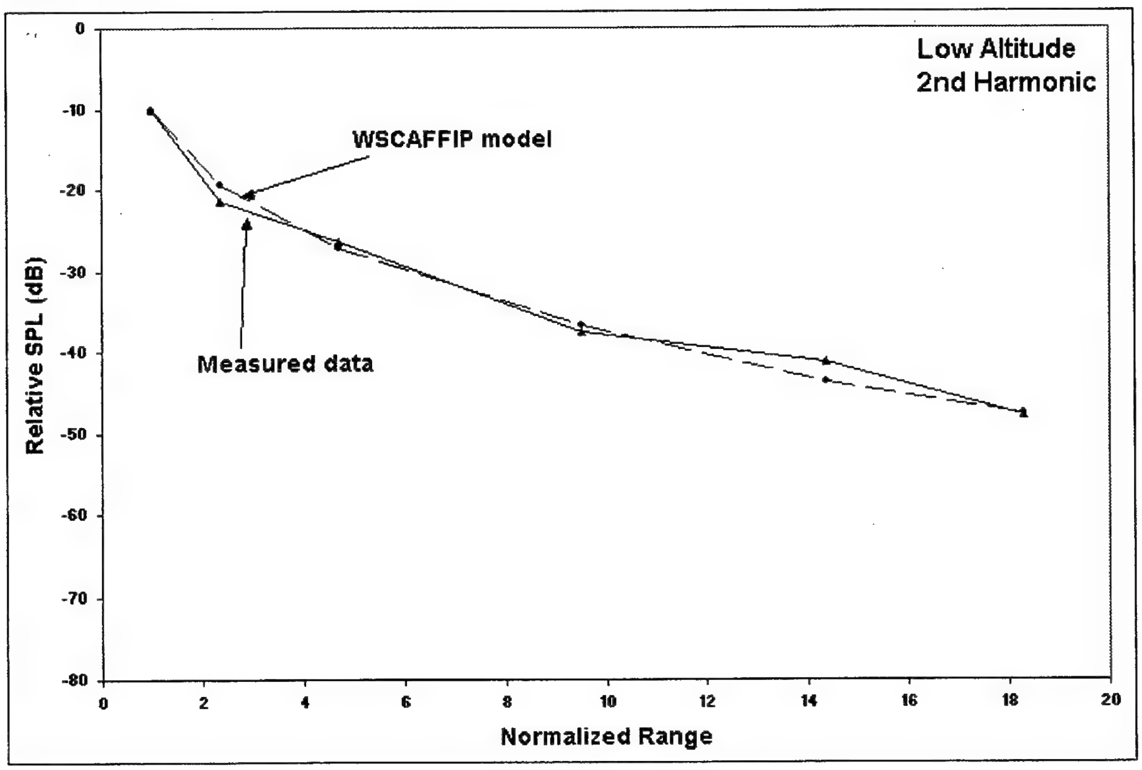


Figure 6. Comparison between WSCAFFIP model and measured data for second harmonic at low altitude.

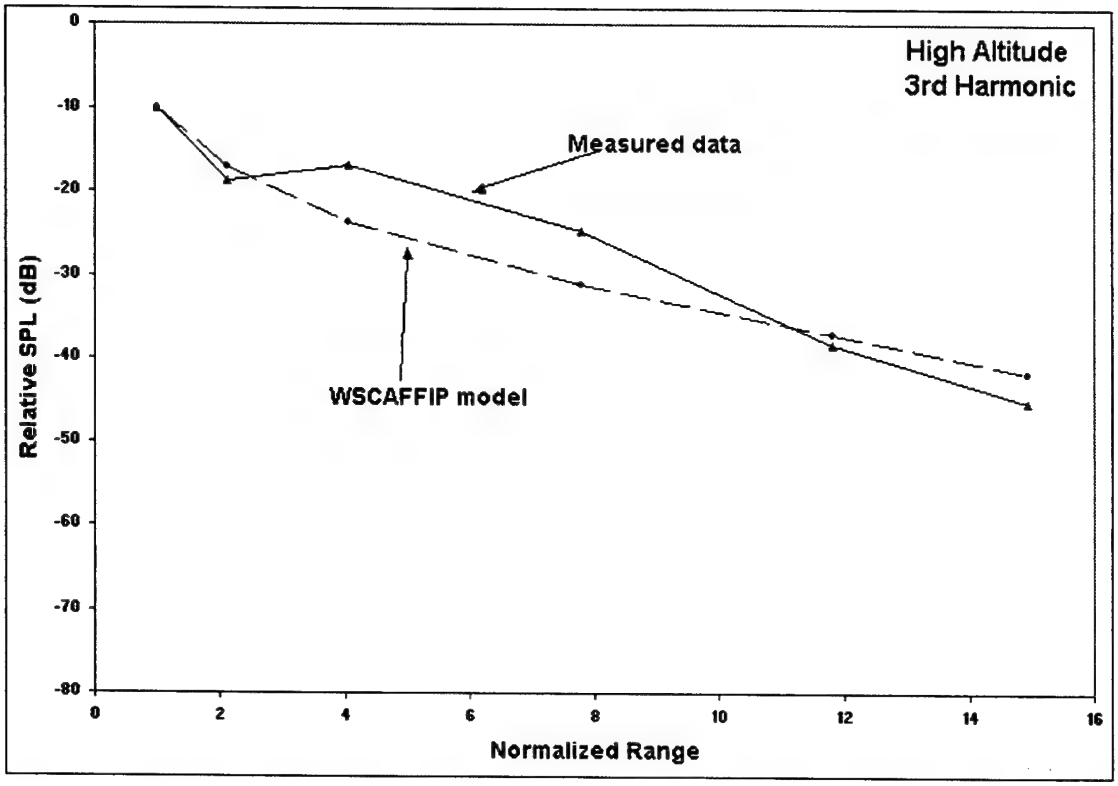


Figure 7. Comparison between WSCAFFIP model and measured data for third harmonic at high altitude.

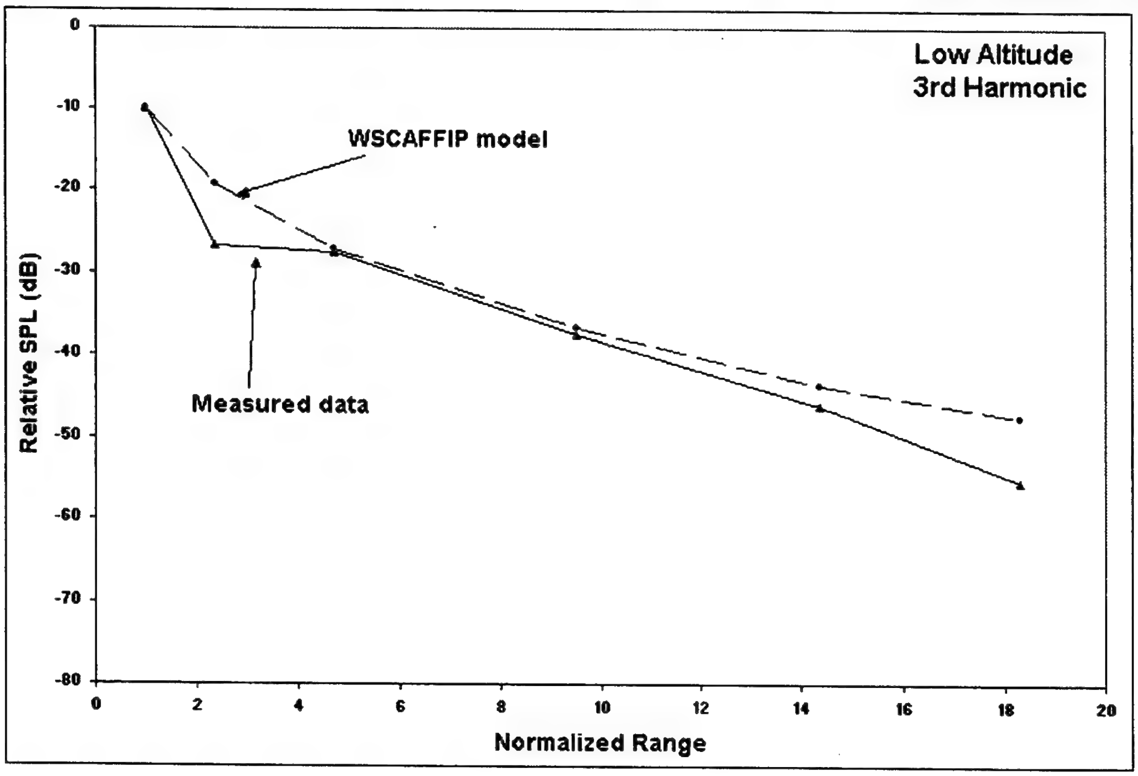


Figure 8. Comparison between WSCAFFIP model and measured data for third harmonic at low altitude.

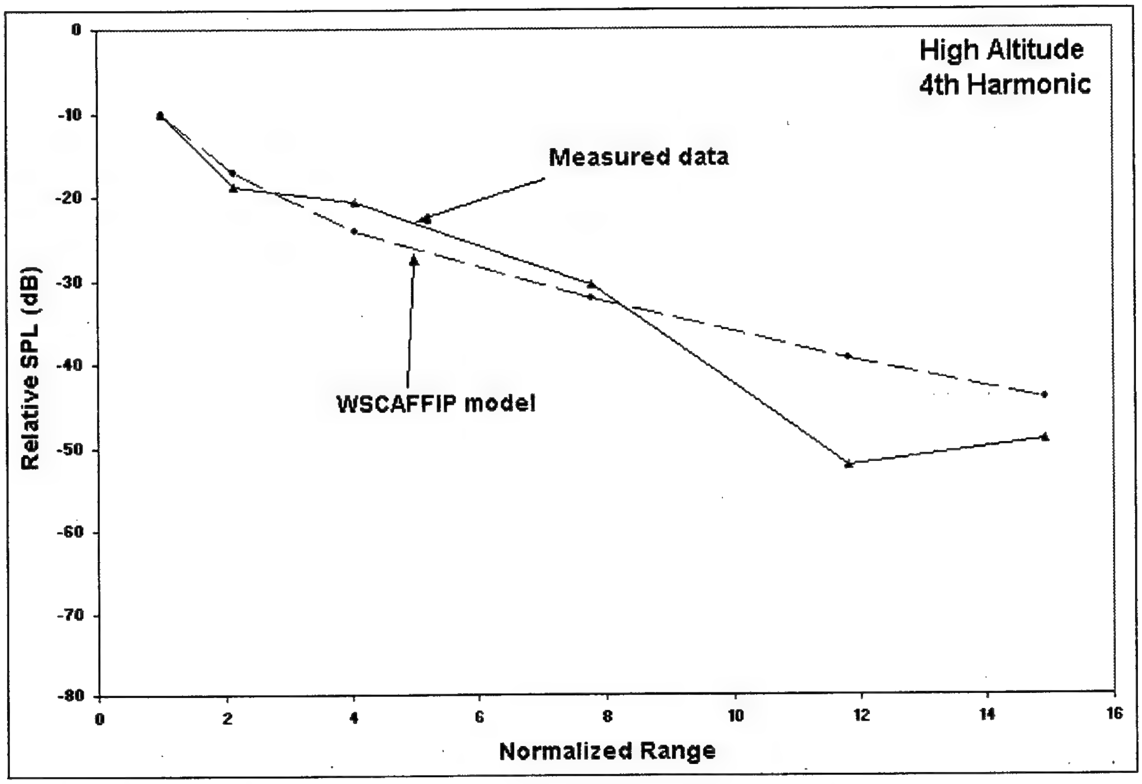


**Figure 9. Comparison between WSCAFFIP model and measured data for fourth harmonic at high altitude.**

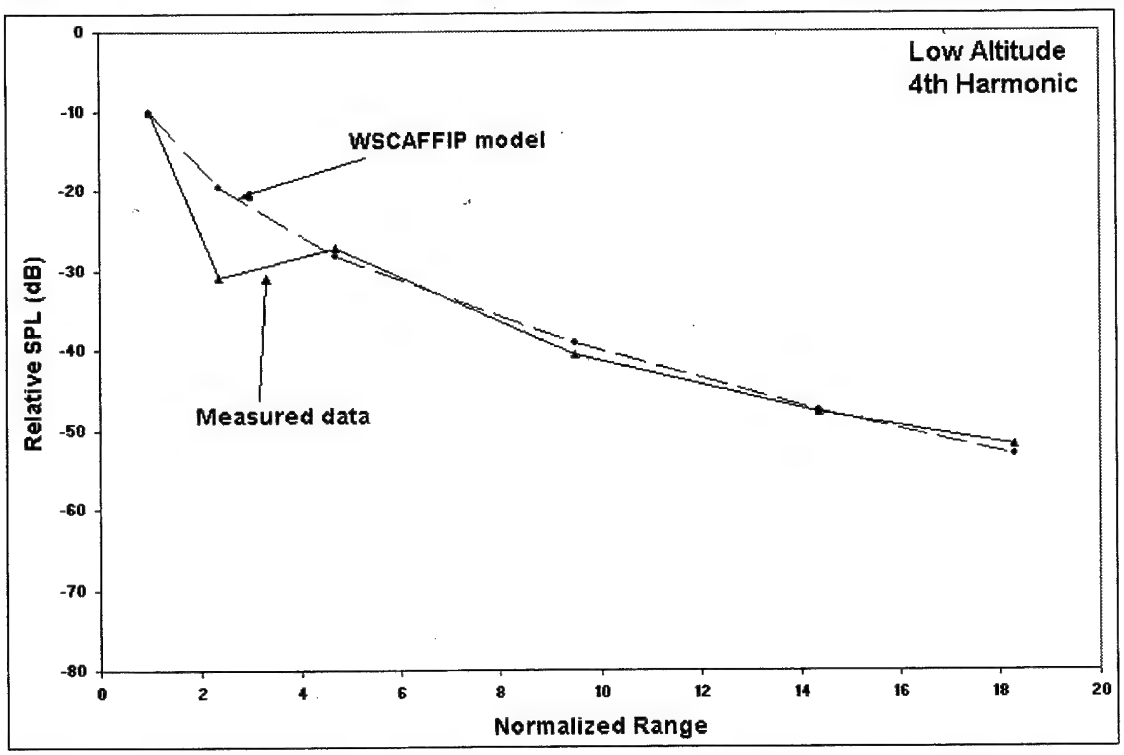


**Figure 10. Comparison between WSCAFFIP model and measured data for fourth harmonic at low altitude.**

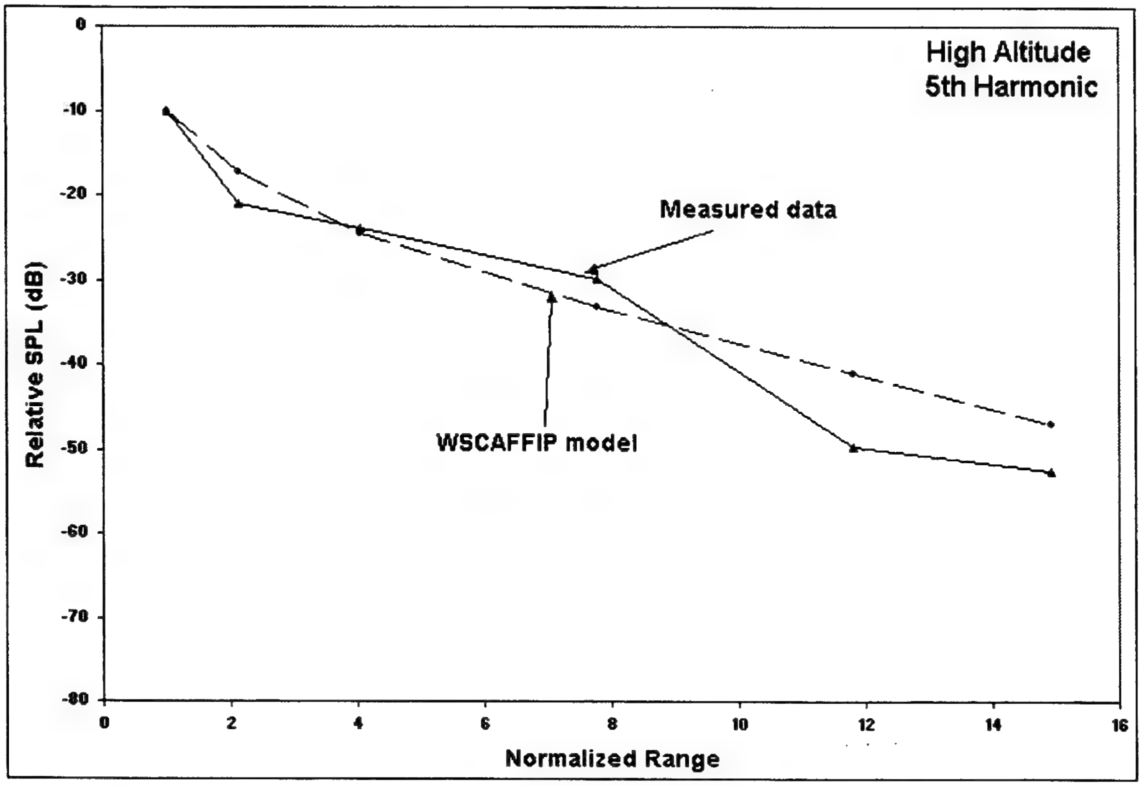


Figure 11. Comparison between WSCAFFIP model and measured data for fifth harmonic at high altitude.

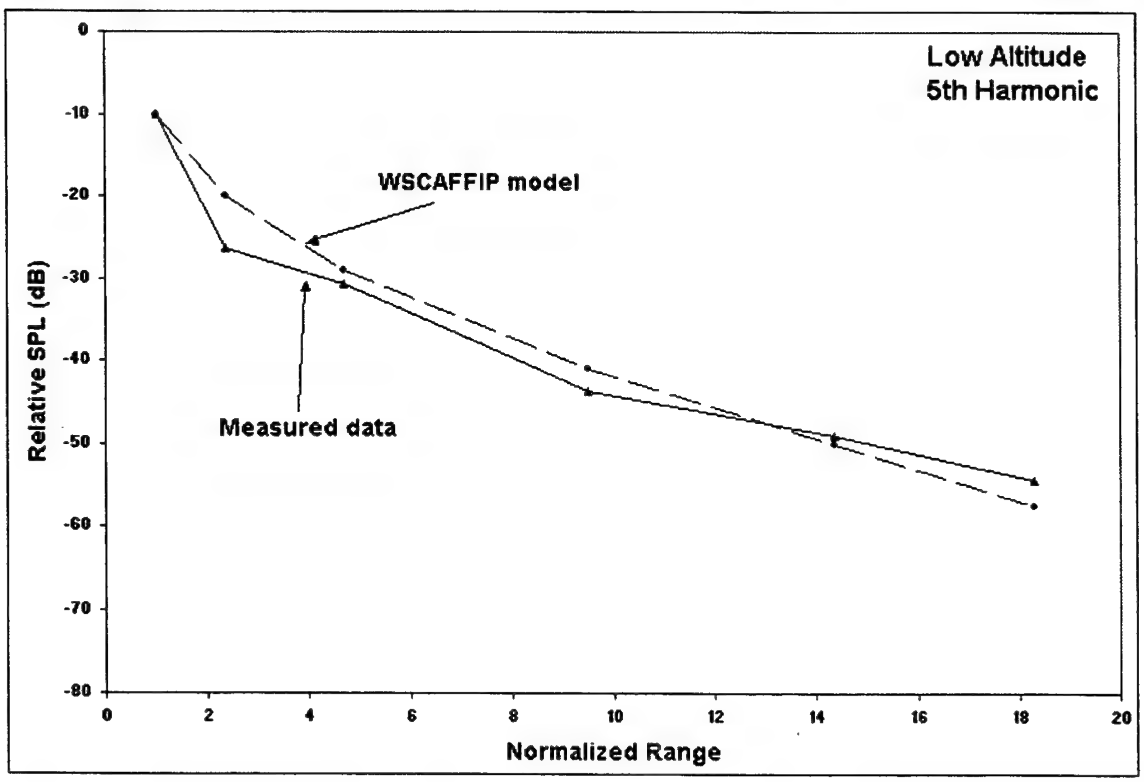


Figure 12. Comparison between WSCAFFIP model and measured data for fifth harmonic at low altitude.

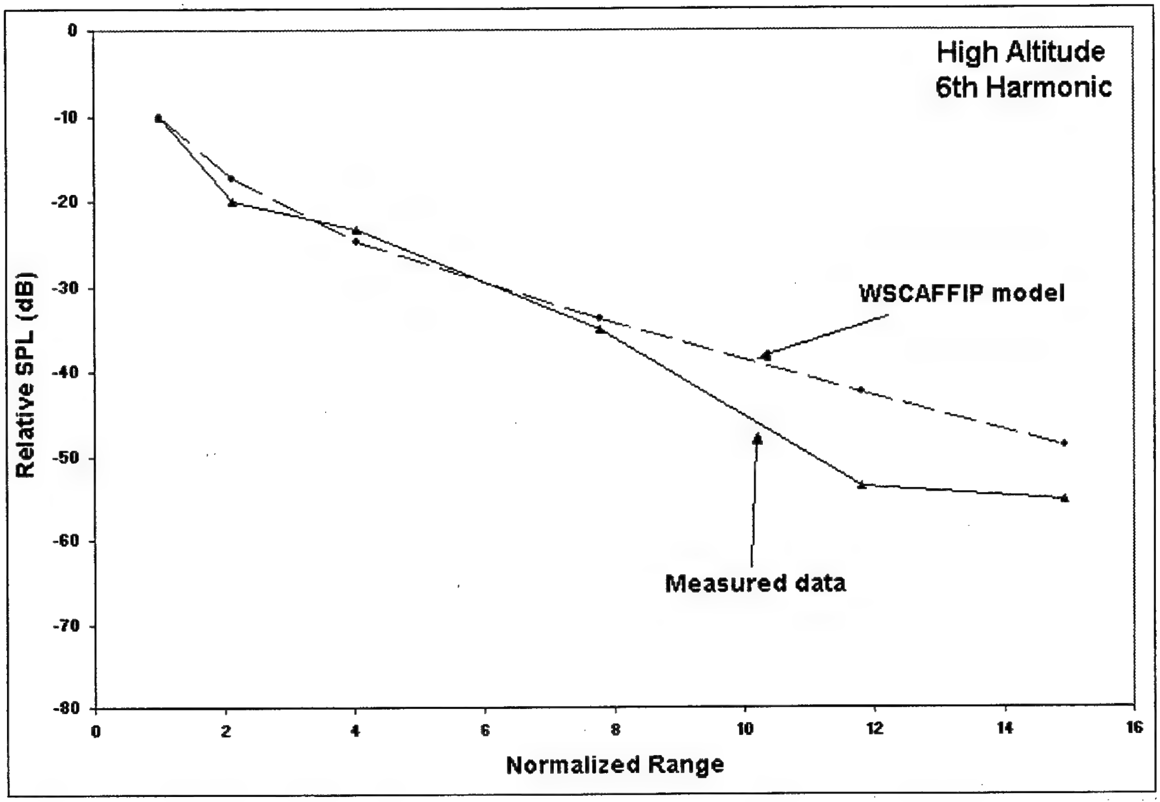


**Figure 13. Comparison between WSCAFFIP model and measured data for sixth harmonic at high altitude.**

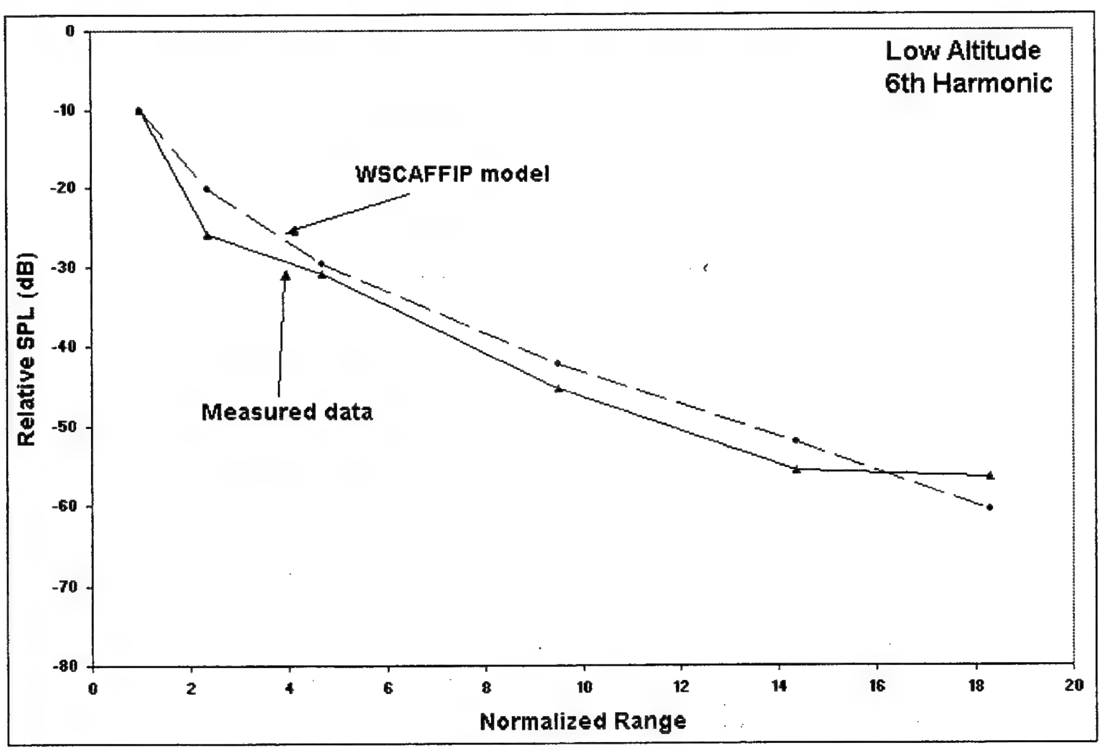


**Figure 14. Comparison between WSCAFFIP model and measured data for sixth harmonic at low altitude.**

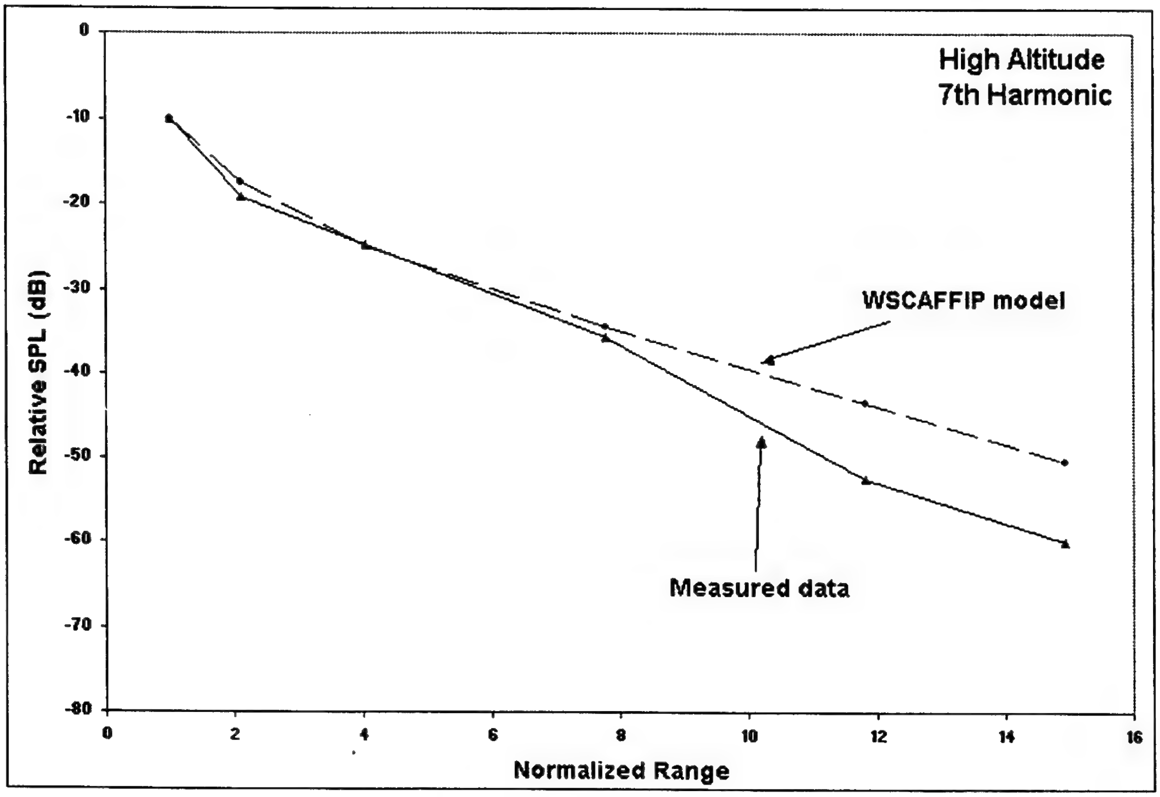


**Figure 15. Comparison between WSCAFFIP model and measured data for seventh harmonic at high altitude.**

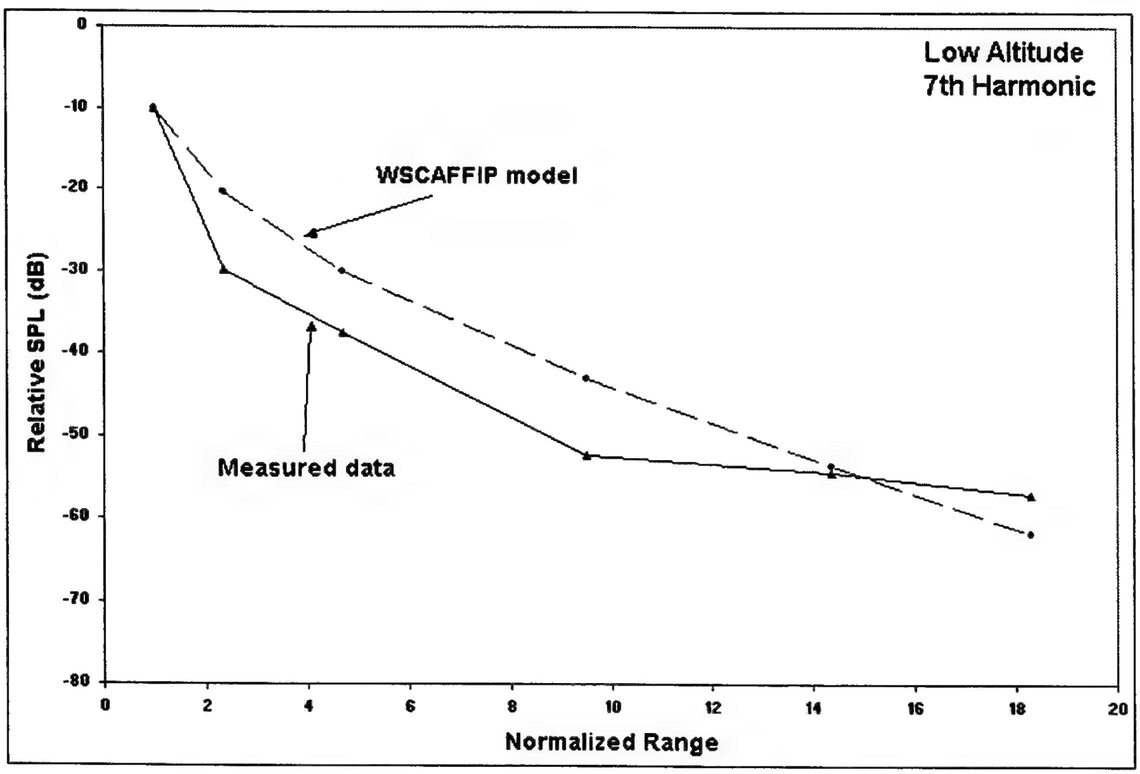


**Figure 16. Comparison between WSCAFFIP model and measured data for seventh harmonic at low altitude.**

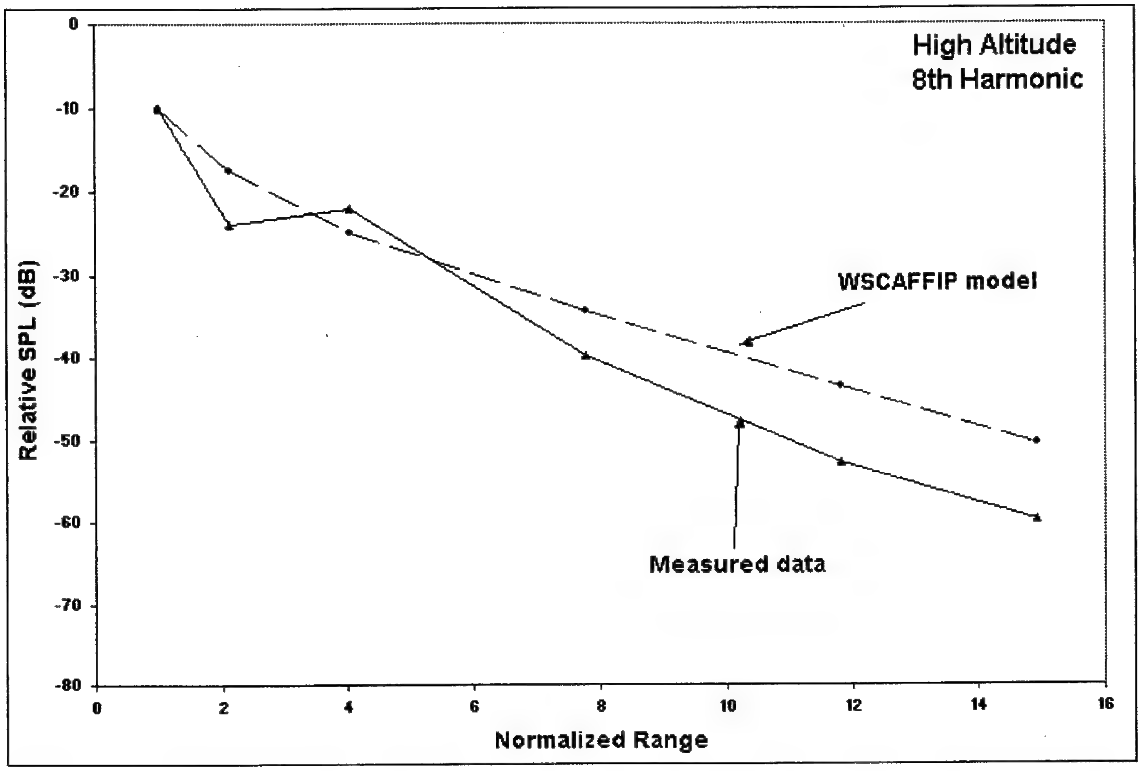


Figure 17. Comparison between WSCAFFIP model and measured data for eighth harmonic at high altitude.

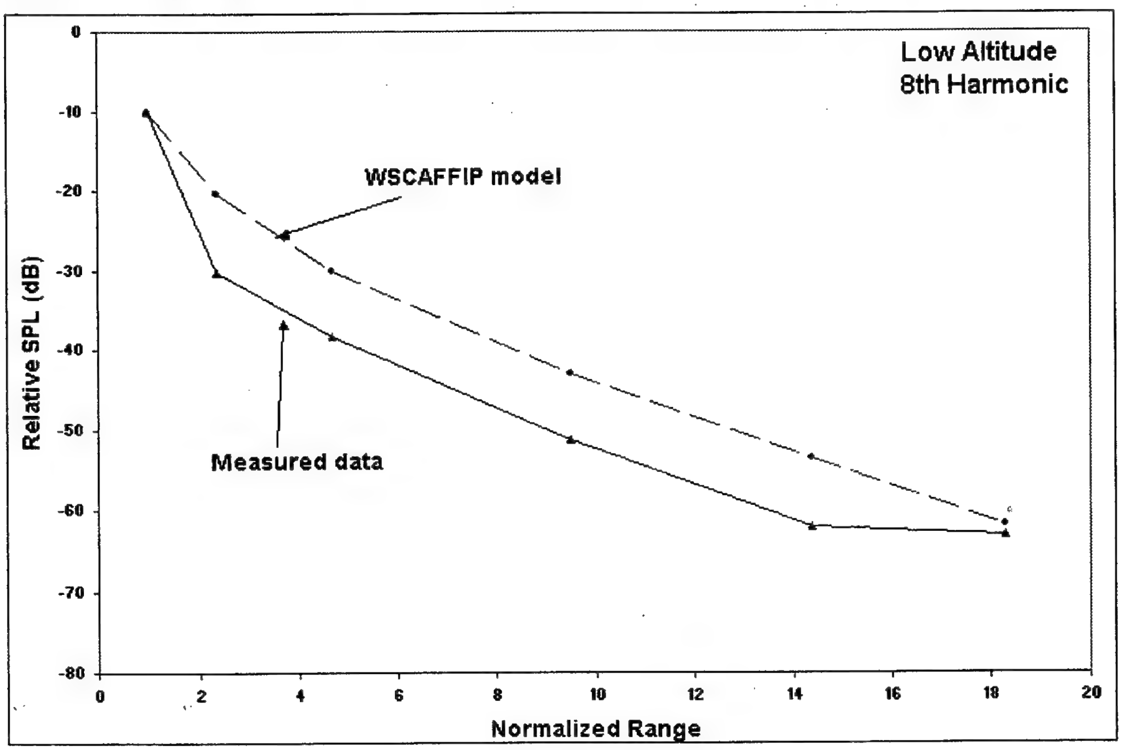


Figure 18. Comparison between WSCAFFIP model and measured data for eighth harmonic at low altitude.

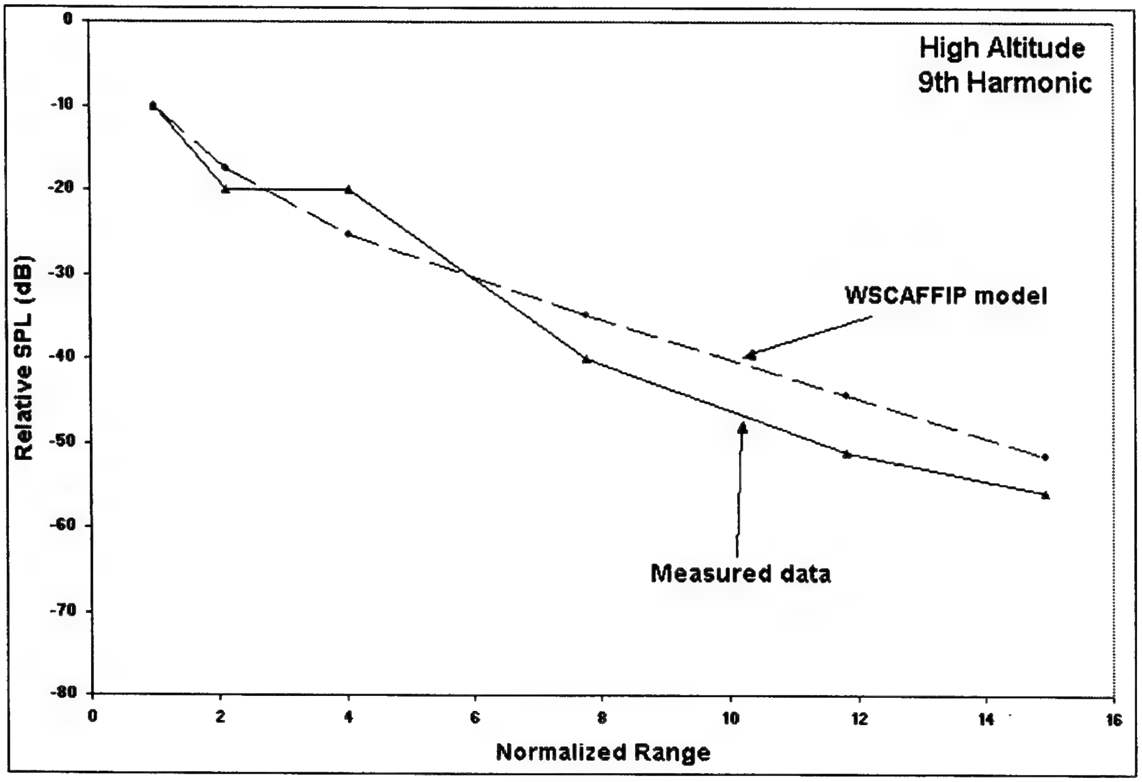


**Figure 19. Comparison between WSCAFFIP model and measured data for ninth harmonic at high altitude.**

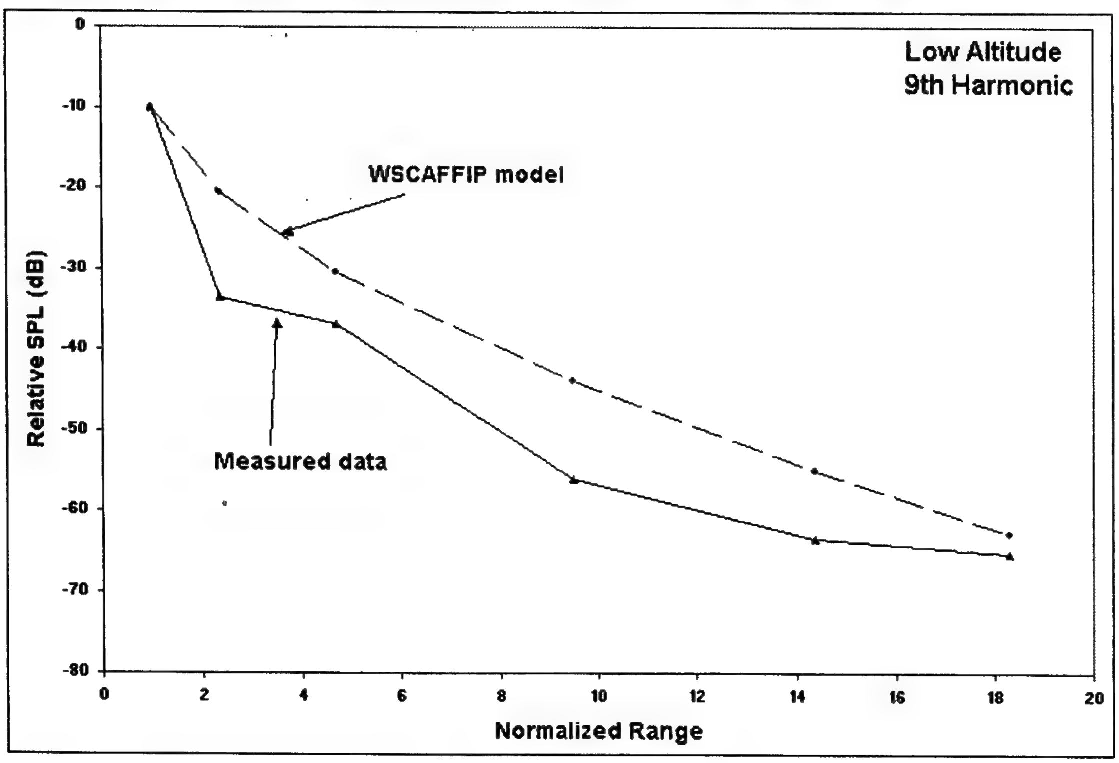


**Figure 20. Comparison between WSCAFFIP model and measured data for ninth harmonic at low altitude.**

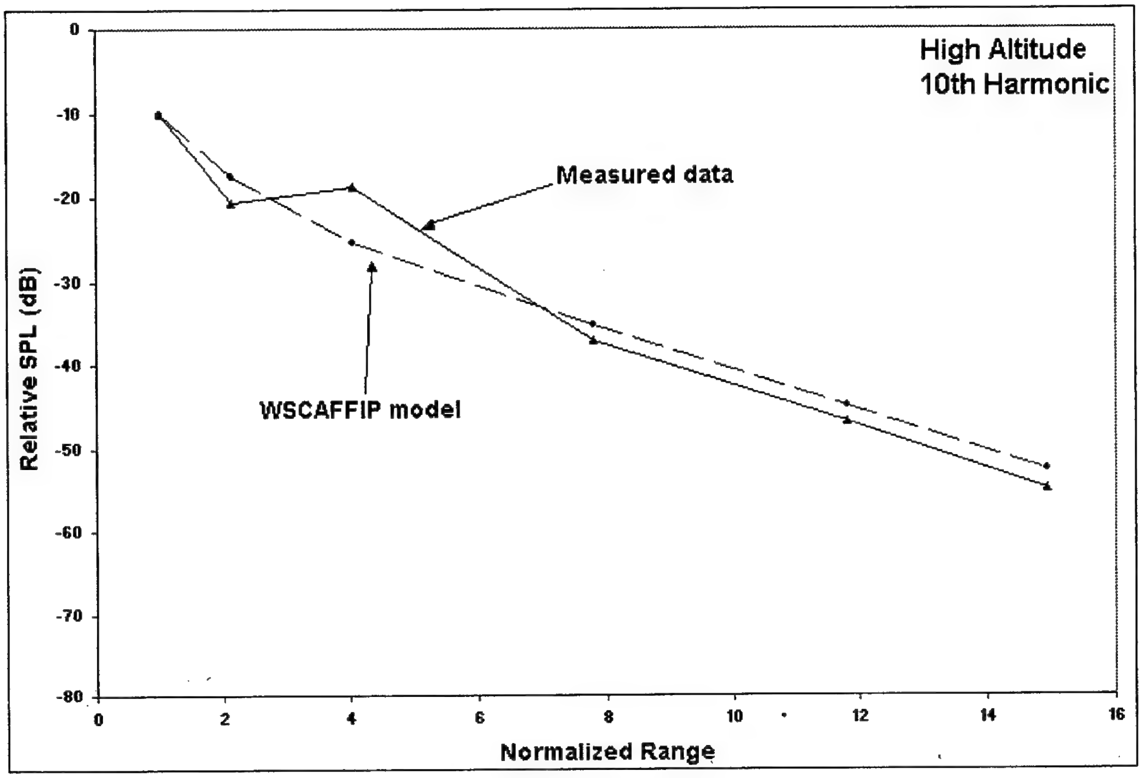


Figure 21. Comparison between WSCAFFIP model and measured data for tenth harmonic at high altitude.

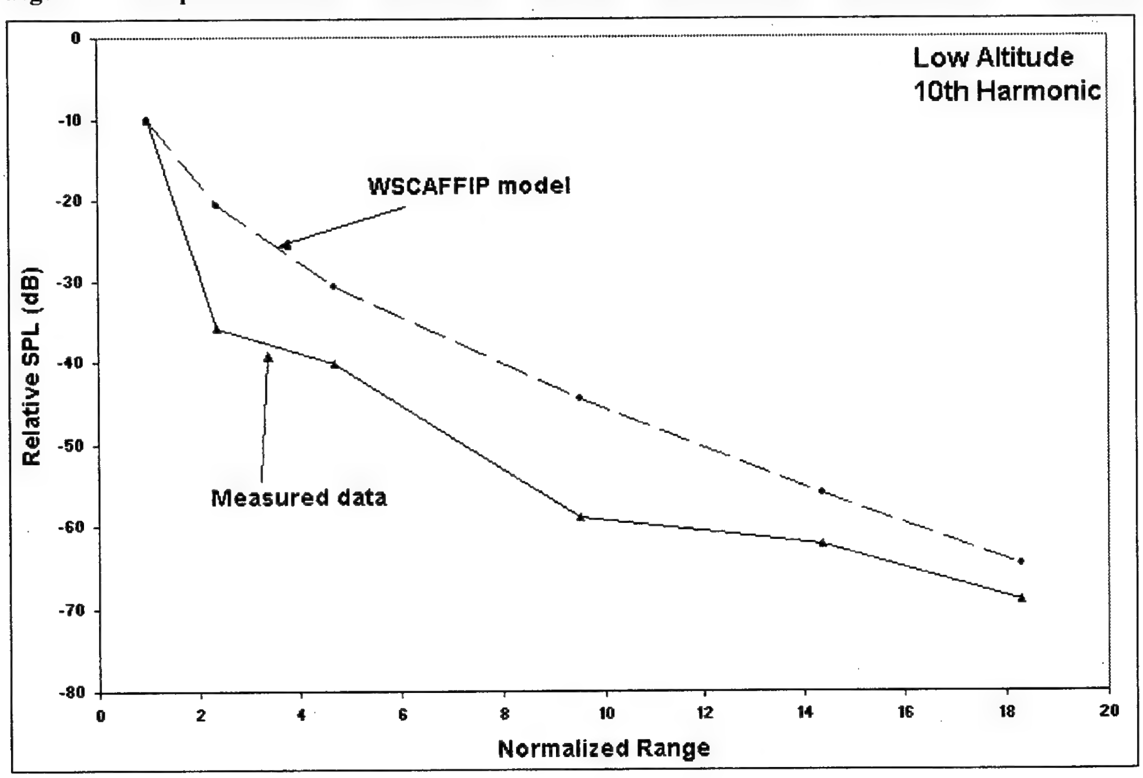


Figure 22. Comparison between WSCAFFIP model and measured data for tenth harmonic at low altitude.

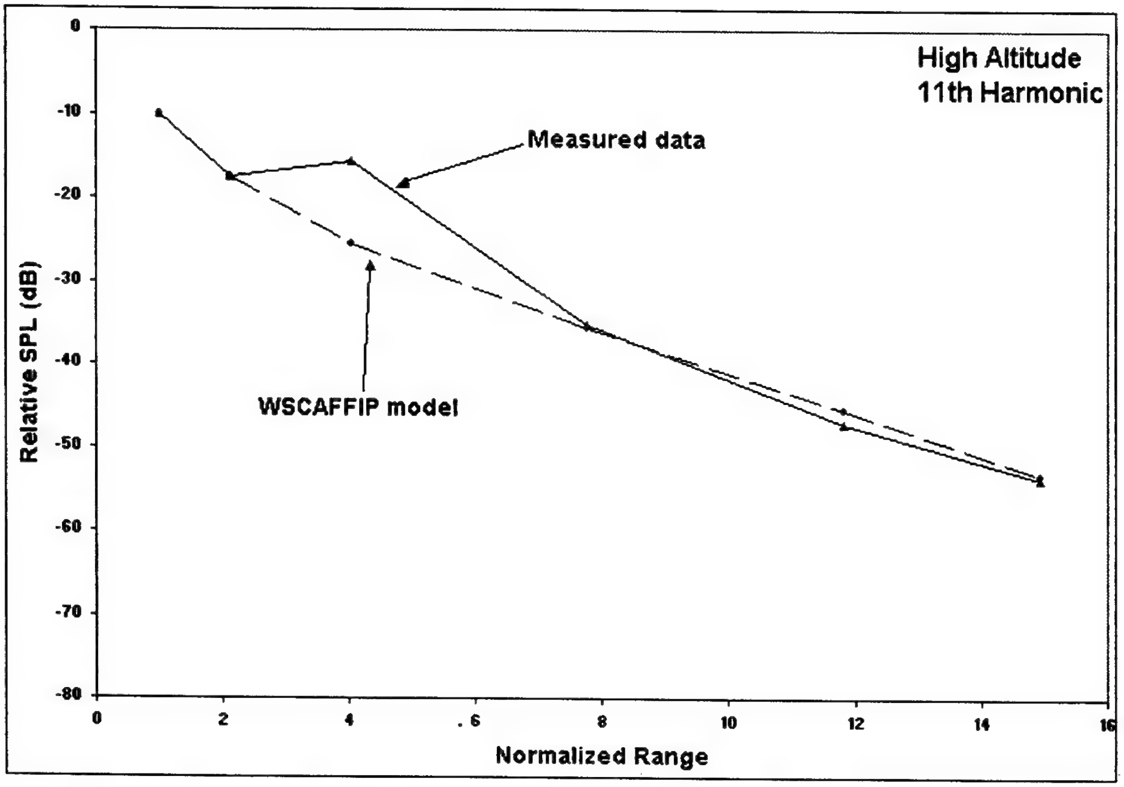


Figure 23. Comparison between WSCAFFIP model and measured data for eleventh harmonic at high altitude.

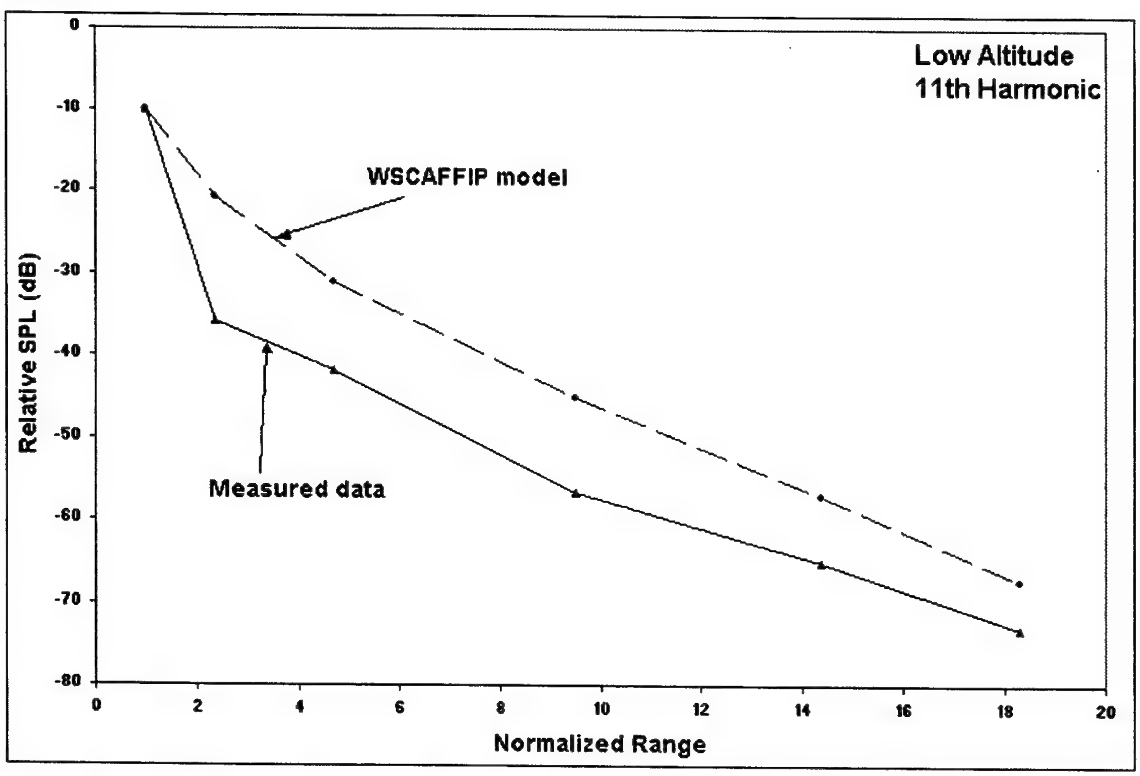


Figure 24. Comparison between WSCAFFIP model and measured data for eleventh harmonic at low altitude.

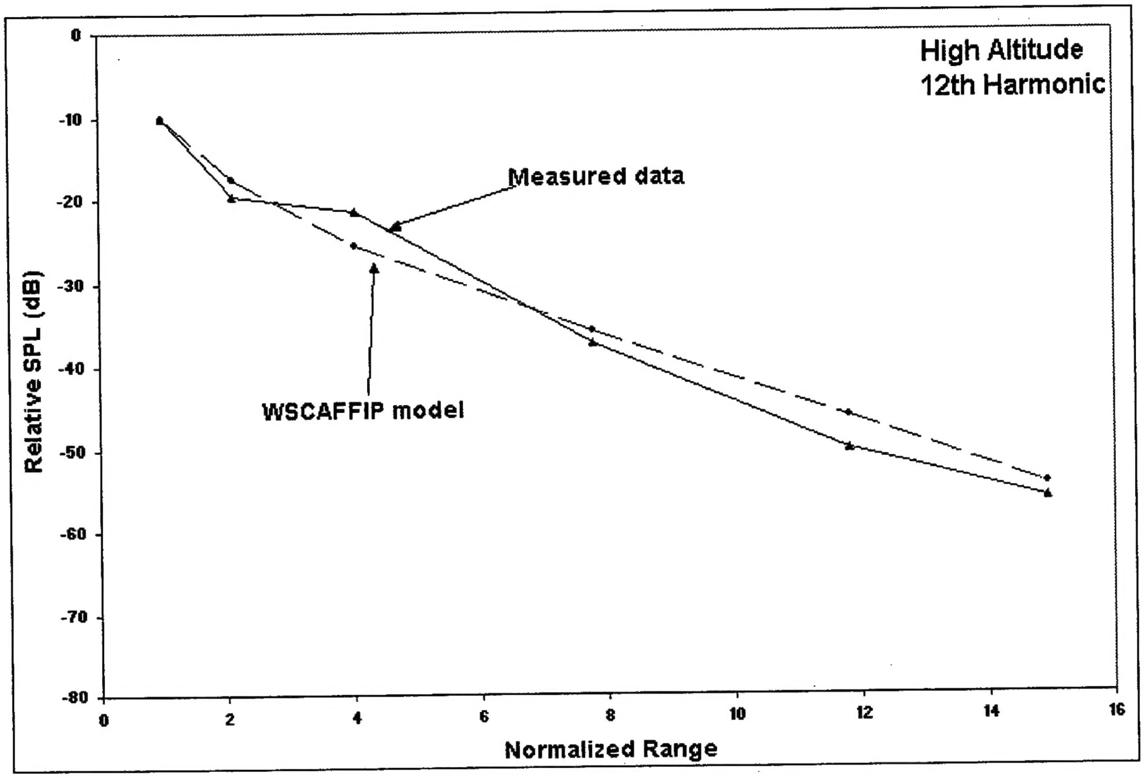


Figure 25. Comparison between WSCAFFIP model and measured data for twelfth harmonic at high altitude.

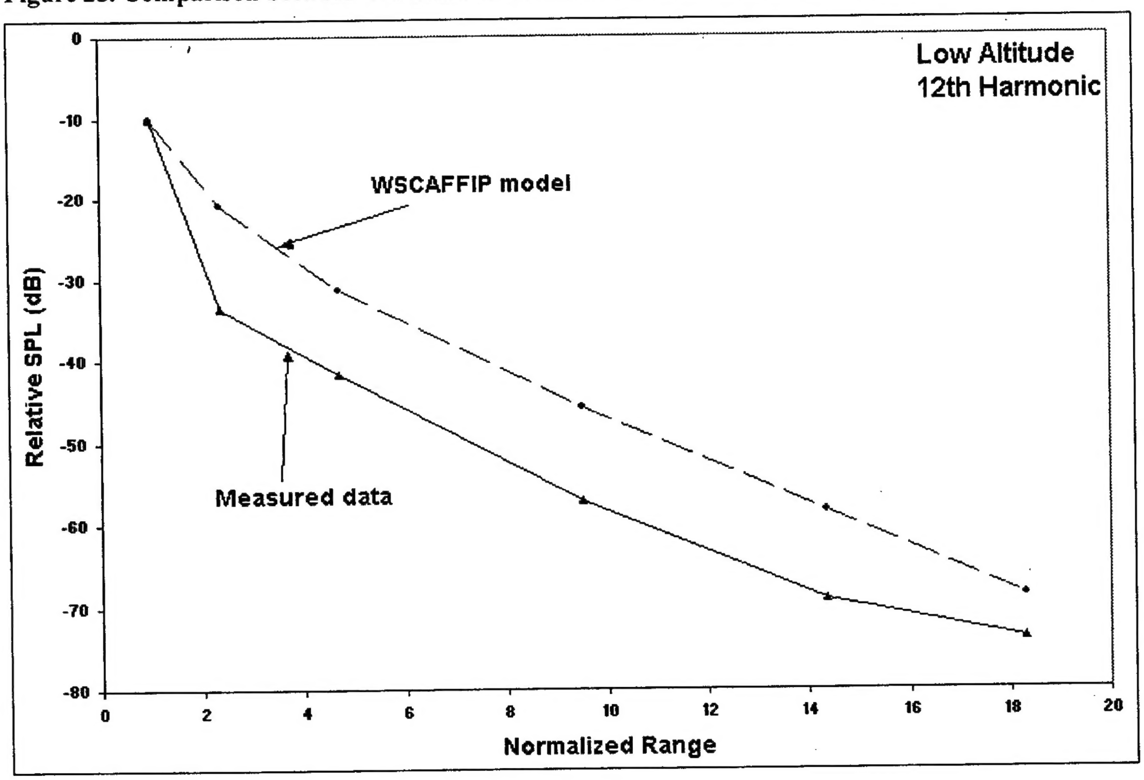


Figure 26. Comparison between WSCAFFIP model and measured data for twelfth harmonic at low altitude.

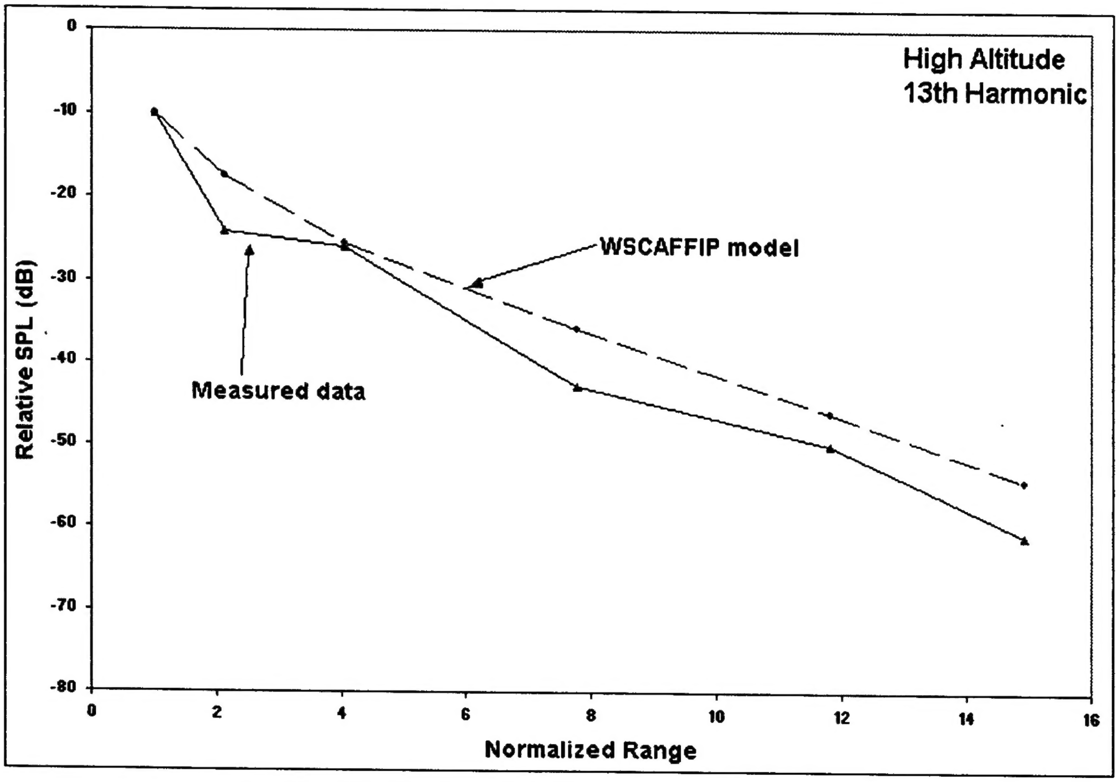


**Figure 27. Comparison between WSCAFFIP model and measured data for thirteenth harmonic at high altitude.**

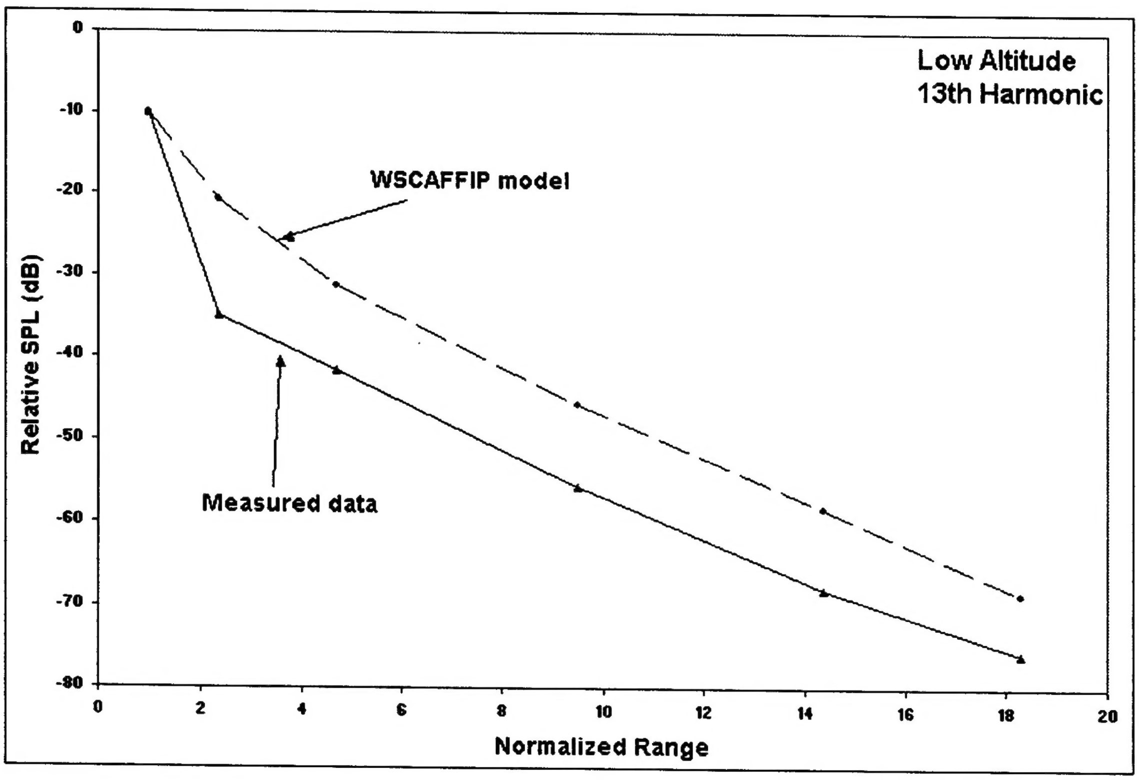


**Figure 28. Comparison between WSCAFFIP model and measured data for thirteenth harmonic at low altitude.**

## 4. Conclusions

The measured SPL data from a hovering rotorcraft generally supported the theoretical attenuation levels from the WSCAFFIP model. There were some discrepancies, but these could be due to an incomplete knowledge of meteorological conditions between the sound source and receiver at all hover points. Also, the ground may have attenuated the sound to a greater extent than the model indicated, especially at the higher frequencies.

## 5. Recommendations

In any future investigations of this sort, SLAD recommends that meteorological data be taken at several altitudes and points between the receiver and sound source. This is probably the most important part of the WSCAFFIP model, and the one that will best facilitate the modeling of sound propagation through the atmosphere.

## Bibliography

1. Noble, John M., User's Manual for the Scanning Fast Field Program (SCAFFIP) General Version 1.0 (U), ARL-TR-545, U.S. Army Research Laboratory, White Sands Missile Range, NM, January 1995. (UNCLASSIFIED)
2. Noble, John M., & Michael Barnes, Comparison between the Scanning Fast-Field Program and Helicopter Data (U), ARL-TR-824, U.S. Army Research Laboratory, White Sands Missile Range, NM, December 1995. (UNCLASSIFIED)